Check List 10(1): 10–17, 2014

ISSN 1809-127X (available at *www.checklist.org.br*)

Check List
Journal of species lists and distribution

Lists of Species

The Social Wasp Community (Hymenoptera, Vespidae) in an Area of Atlantic Forest, Ubatuba, Brazil

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Abstract: The Brazilian Atlantic Forest is of great relevance to biological conservation, and is among the areas in South America with the highest levels of diversity and endemism. The aim of this study was to survey the social wasp species in the subfamily Polistinae in Ubatuba, São Paulo state, in southwestern Brazil. Collecting work was conducted from May 2007 to May 2008 using attractive PET bottle traps and active searching. Twenty-one species belonging to eight genera were found, among which some may be considered rare in southeastern Brazil such as Mischocyttarus parallelogrammus and Polybia catillifex. The most abundant species were Agelaia angulata (64.31%), Agelaia nr. centralis (10.08%) and Angiopolybia pallens (8.49%). A correlation between species richness and relative humidity ($r = 0.6435$; $p = 0.0176$) was observed. Values of species richness were a little higher in the super humid (Sm = 11) than in the less humid (Sm = 9) season. This suggests that this season may have more favorable environmental conditions for a greater richness of species to found colonies. Despite not having a very high species richness compared with other surveys, the collected species in this study can be considered rare in southeastern Brazil, emphasizing the complexity of the Atlantic Forest biome and its relation to the diversity of wasps.

Introduction

Social wasps (Vespidae, Polistinae) are remarkably abundant in Brazil (Raveret-Richter 2000), acting as predators, nectar collectors (Suzuki 1978; Carpenter and Marques 2001; Aguiar and Santos 2007), and prey (Jeanne 1975; Gadagkar 1991; Raw 1997) in the food chain.

Due to the importance and abundance of the taxon, studies on the diversity and abundance of social wasps have been conducted across different regions and environments, such as cultivated fields and human-modified environments (Rodrigues and Machado 1982; Marques 1989; Marques *et al.* 1993; Santos 1996; Lima *et al.* 2000; Marques *et al.* 2005; Ribeiro Junior 2008; Santos *et al.* 2009a; Santos *et al.* 2009b; Alvarenga *et al.* 2010; Auad *et al.* 2010; Santos and Presley 2010; Souza *et al.* 2011; Tanaka Junior and Noll 2011; Locher 2012), in areas of "cerrado" (semi-deciduous tropical forest or Brazilian savanna) (Richards 1978; Diniz and Kitayama 1994; Mechi 1996; 2005; Melo *et al.* 2005; Souza and Prezoto 2006; Elpino-Campos *et al.* 2007; Souza *et al.* 2008; Santos *et al.* 2009b; Lima *et al.* 2010; Henrique-Simões *et al.* 2011; Tanaka Junior and Noll 2011), "campos rupestres" montane savannas (characteristic vegetation of areas above 800-900 m of altitude that presents open vegetation with a stratum of monocot herbs, sub-shrubs and shrubs of dicots) (Silva-Pereira and Santos 2006; Clemente 2009; Prezoto and Clemente 2010), "caatinga", (Tropical deciduous xerophytic woodland) (Melo *et al.* 2005; Santos *et al.* 2006; Santos *et al.* 2009a), riparian forest (Mechi 1996; Silveira *et al.* 2008; Souza *et al.* 2008; Clemente 2009; Souza *et al.* 2010; Henrique-Simões *et al.* 2011; Pereira and Antonialli-Junior 2011; Locher 2012), different environments of the Atlantic Forest (Melo *et al.* 2005; Hermes and Köhler 2006; Santos *et al.* 2007; Souza *et al.* 2008; Clemente 2009; Gomes and Noll 2009; Lima *et al.* 2010; Prezoto and Clemente 2010; Tanaka Junior and Noll 2011), and the Amazon Forest (Raw 1998; Silveira 2002; Silveira *et al.* 2005; Morato *et al.* 2008; Silveira *et al.* 2008; Silva and Silveira 2009).

Inventorying an area is the first step towards its conservation and rational use (Melo *et al.* 2005). By undertaking a survey of species of social wasps, several aspects of their biology and behavior must be considered, such as colony seasonality, foraging activity, and nesting habits. Brazilian rainforests represent a peak of biodiversity, and in this sense, certain localities possess the greatest abundance and richness of known species on the planet (Machado *et al.* 1998), including in their diversity of social wasps (Richards 1978).

The social wasps in Brazil have the asynchronous colony cycle. This pattern has been well-described for the genera *Mischocyttarus*, *Polistes* and *Polybia* (Gobbi and Zucchi 1980; Simões and Mecchi 1983; Gobbi 1984; Simões *et al.* 1985; Gobbi and Simões 1988; Marques *et al.* 1992; Giannotti and Machado 1994; Giannotti *et al.* 1995; Giannotti 1998). On the other hand, the foraging activity of Polistinae may be primarily limited by physical factors (Spradbery 1973), such as light intensity, temperature, air humidity, and wind speed, and some studies have shown that individual wasps forage more intensively during the warmest and least humid hours of the day (Giannotti *et al.* 1995; Andrade and Prezoto 2001; Resende *et al.* 2001).

The present article presents the results of the first inventory of social wasps in an area of the Atlantic Forest in the northern coastal region of São Paulo state, in southwestern Brazil, emphasizing the importance of this

group for further studies on the Conservation Biology of the region. In addition, we sought to analyze and verify the existence of relationships between the temporal distribution of humidity and temperature and the richness and abundance of species identified.

Materials and Methods

Study area

The study site was in the Angelim Rainforest, a nature reserve in ombrophilous dense forest, located in the Atlantic Forest biome (Veloso *et al.* 1991), situated in Ubatuba city, (23°23′ S, 45°03′ W) São Paulo state, southwestern Brazil (Figure 1). The area is privately owned by Paul and Edna Thomsen and contains a total of 760 ha covered by native vegetation. Eighty percent of the area occurs within the State Park of Serra do Mar. The farm has several trails that provide access to sites in dense forest, some of which accompany the course of the Angelim River that originates in the nearby hills within the property.

The climate in the region, according to Köppen's classification (Köppen 1948), is tropical rainforest with an average annual temperature of approximately 26.72°C, and constant humidity with an annual average humidity of 73.45%. The region has two seasons: (1) super humid with frequent rains from October to April, and (2) a less humid season from May to September with less constant rainfall, but without any water deficit (Bencke and Morellato 2002).

Collecting procedures

Twenty-five points were marked along the studied trail, with a distance of at least 100 meters between each in order to avoid the occurrence of pseudo-replicates; that is, individuals from the same wasp colony collected at separate sampling sites. Thirteen monthly collecting rounds were performed from May 2007 to May 2008, with each consisting of two days of fieldwork at the study site, with a one-week interval between. The relative humidity and environmental temperature at each sampling point were measured by digital thermo-hygrometer, making it possible to calculate a monthly average of these climatic variables and correlate them to local wasp diversity.

Attractive traps

Attractive traps made from two-liter plastic PET bottles (Melo *et al.* 2001; Souza and Prezoto 2006) were installed at each marked point. Four circular holes were made in each bottle and 200 mL of attractive liquid were placed inside. Two types of attractants were used: 1) guava juice, or 2) a blend containing 84 grams of sardines (equivalent to a tin) per liter of water. The traps were placed monthly at each of the 25 sampling points, and removed after one week. Individual wasps found in the bottles were collected with a sieve and tweezers and placed in vials to be fixed in 70% ethanol.

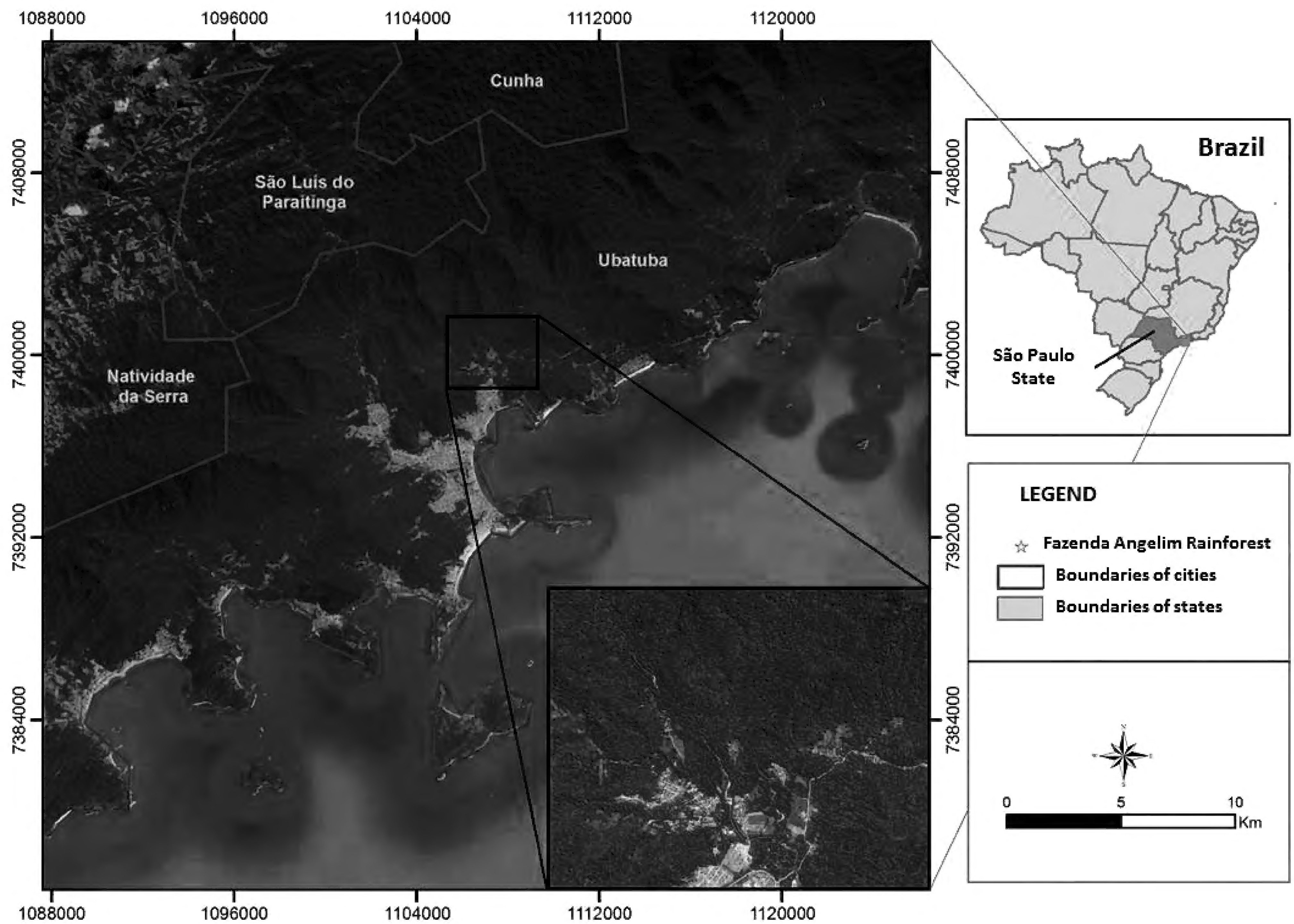

Figure 1. Location of the study area.

Active searching

Active searching relied on the use of entomological nets to search for individuals on pathways and trails in the area, and checking flowers, tree cavities, broad-leafed plants and buildings for the presence of wasps in the study area (Elpino-Campos *et al.* 2007). Individuals were actively sampled during the two days every month in which the area was visited for a total of 10 hours of monthly sampling effort.

Identification of collected material

All specimens were collected in accordance with the permit number 11413-1 of the Brazilian Institute of Environment and Renewable Natural Resources, IBAMA, and were deposited in the Entomological Collection at the Department of Zoology, Universidade Estadual Paulista "Júlio de Mesquita Filho" (UNESP), campus of Rio Claro, SP, Brazil and at the Entomological Collection at Museu Paraense Emílio Goeldi, Bélem, PA, Brazil. Species were identified through the use of dichotomous keys (Richards 1978; Carpenter and Marques 2001; Pickett and Wenzel 2007; Silveira *et al.* 2008; Cooper 1997) and by comparison with specimens in the aforementioned collections. Voucher specimens were deposited on the Entomological Collection at the Department of Zoology UNESP Rio Claro or on the Entomological Collection at Museu Paraense Emílio Goeldi (Table 2).

Data analysis

The relative abundance of each species was calculated by dividing the abundance of the species by the total number of individuals collected. To assess the constancy of species in relation to monthly samplings, we used the formula C = P x 100 / N, proposed by Bodenheimer (1955 apud Silveira-Netto *et al.* 1976), where:

P = number of samples containing a certain species;

N = total number of samples;

Data were grouped into the following categories: (1) constant species, present in over 50% of the samples; (2) accessory species, present in 25% to 50% of samples (3) accidental species, present in less than 25 % of samples.

To verify the existence of significant differences in the richness and abundance of species of wasps collected during different seasons, the Mann-Whitney U test was performed, using the software BioEstat 5.0 (Ayres *et al.* 2007). In addition, we applied the Spearman correlation test (BioEstat 5.0) to verify a possible relationship between the diversity of social wasps and environment temperature and relative humidity, which were measured monthly.

Results

A total of 2104 social wasp individuals (Vespidae, Polistinae) were collected, representing 21 species in eight genera (Table 1).

Table 2 presents the total abundance (A), relative abundance (RA%), the constancy (C), and richness (S) for species and samples found in the Angelim Rainforest, and how they were distributed throughout the year. *Agelaia angulata* had the highest abundance (A = 1353), representing more than half of the total number of individuals collected, with a relative abundance of 64.31%, and thus was considered the dominant species. Relative abundances were higher than 1% for the following species:

Table 1. Relative abundance of each species and species richness for each season, less humid (May to September) and super humid (October to April).

TAXON	RELATIVE ABUNDANCE (%)	
	LESS HUMID SEASON	SUPER HUMID SEASON
Epiponini		
Agelaia angulata (Fabricius, 1804)	82.60	49.61
Agelaia sp. nr. *centralis* (Cameron, 1907)	7.47	12.17
Agelaia multipicta (Haliday, 1836)	0.75	0.60
Agelaia vicina (de Saussure, 1854)	0.64	2.49
Angiopolybia pallens (Lepeletier, 1836)	2.45	14.14
Apoica pallens (Fabricius, 1804)	0.32	0.17
Polybia bifasciata de Saussure, 1854	0.00	0.43
Polybia cattilifex Moebius, 1856	1.28	5.66
Polybia fastidiosuscula de Saussure, 1854	0.11	0.60
Polybia ignobilis (Haliday, 1836)	0.32	0.17
Polybia jurinei de Saussure, 1854	0.53	0.34
Polybia occidentalis (Olivier, 1791)	1.07	6.60
Protopolybia exigua (de Saussure, 1854)	0.11	0.00
Synoeca cyanea (Fabricius, 1775)	0.32	0.09
Mischocyttarini		
Mischocyttarus cassununga (von Ihering, 1903)	0.00	0.77
Mischocyttarus parallelogrammus Zikán, 1935	0.43	0.69
Mischocyttarus rotundicolis (Cameron, 1912)	0.11	0.34
Mischocyttarus socialis (de Saussure, 1854)	1.17	2.40
Mischocyttarus wagneri (Buysson, 1908)	0.11	0.00
Polistini		
Polistes carnifex (Fabricius, 1775)	0.00	0.17
Polistes versicolor (Olivier, 1791)	0.21	2.57
Species richness	**18**	**19**

A. nr. *centralis* (10.08%), *Angiopolybia pallens* (8.94%), *Polybia occidentalis* (4.13%), *Polybia catillifex* (3.71%), *Mischocyttarus socialis* (1.85%), *Agelaia vicina* (1.66%) and *Polistes versicolor* (1.52%)

The species *Agelaia vicina*, in spite of being among the most abundant species, was considered an incidental species, found in only six samples along the entire period studied. Contrary to this situation, the populations of *A. multipicta* and *M. parallelogrammus* presented small relative abundances but were constant species, appearing in eight and seven of the 13 months sampled, respectively (Table 2).

Among the constant species: *Agelaia angulata*, *A.* nr. *centralis*, *A. multipicta*, *Angiopolybia pallens*, *Polybia catillifex*, *P. occidentalis*, *Mischocyttarus parallelogrammus*, *M. socialis* and *Polistes versicolor*, only *Agelaia angulata* and *A.* nr. *centralis* showed a constancy of 100%, while *Angiopolybia pallens* was not sampled in June 2007 and *M. socialis* was not sampled in October 2007 (Table 2).

The species considered as accidental were *Polybia bifasciata*, *P. fastidiosuscula*, *P. ignobilis*, *Protopolybia exígua*, *Synoeca cyanea*, *Mischocyttarus wagneri* and *Polistes carnifex*. We collected only one individual of the species *Protopolybia exigua*, in May 2007, and of *Mischocyttarus wagneri* in August 2007 (Table 2).

In Table 3, the relative abundance of each species and species richness for each season (less humid and super humid) are depicted. In the super humid season, 19 species were collected and *Mischocyttarus cassununga*, *Polybia carnifex* and *Polistes bifasciata* were unique for this period. In the less humid season, we found 18 species, with *Mischocyttarus wagneri* and *Protopolybia exigua* being unique for this period. With respect to the species that showed relative abundances greater than 1.0%, only *Agelaia angulata* was more abundant in the less humid season. Being very abundant and with very populous colonies (Richards 1978), *A. angulata* presents adaptations to maintain its population during the months in which food resources are less available, such as nectar and insects. Furthermore, the attractive liquids used in traps may have represented an extra food source (Elpino-Campos *et al.* 2007). The remaining species*: A.* nr. *centralis, A. vicina, Angiopolybia pallens Mischocyttarus socialis, Polistes versicolor, Polybia catillifex and P. occidentalis* were collected during the super humid season. For species with relative abundances less than 1%, it is noted that, excluding *Mischocyttarus wagneri* which was collected only once, all other independent-founding *M. cassununga, M. parallelogrammus, M. rotundicolis, M. socialis, Polistes carnifex* and *P. versicolor* were more abundant at the super humid season. As the large populations of *Agelaia* are better prepared to face shortages of resources, it may be that the tribes Mischocyttarini and Polistini, with smaller colonies, have a greater sensitivity to decreases in temperature, humidity and consequently the shortage of food sources.

Table 2. Total abundance (A), relative abundance (RA%), constancy (C) and richness (S) from May 2007 to May 2008 and species deposition catalogue number. ● = constant species; □= accessory species; X = accidental species; ■ = super humid season; DZRC = Entomological Collection at the Department of Zoology UNESP Rio Claro; MPEG = Entomological Collection at Museu Paraense Emílio Goeldi.

SPECIES	A	RA%	C	MONTHS													CATALOGUE NUMBER
				m	j	j	a	s	o	n	d	j	f	m	a	m	
Agelaia angulata	1353	64.31	●	#	#	#	#	#	#	#	#	#	#	#	#	#	DZRC 1205 - 1219
A. nr. *centralis*	212	10.08	●	#	#	#	#	#	#	#	#	#	#	#	#	#	DZRC 1220 - 1236
A. multipicta	14	0.67	●	#	#	#	#				#		#	#	#		MPEG 11.101.714 - 11.101.725
A. vicina	35	1.66	□	#			#	#		#	#	#					DZRC 1237 - 1251
Angiopolybia pallens	188	8.94	●	#		#	#	#	#	#	#	#	#	#	#	#	DZRC 1254
Apoica pallens	5	0.24	□	#	#		#		#					#			DZRC 1252
Polybia bifasciata	5	0.24	X						#	#		#					MPEG 11.101.714 - 11.101.725
P. catillifex	78	3.71	●	#			#	#	#	#	#	#	#	#	#		DZRC 1261 - 1269
P. fastidiosuscula	8	0.38	X	#					#								DZRC 1259 - 1260
P. ignobilis	5	0.24	X	#			#			#				#			DZRC 1287 - 1287
P. jurinei	9	0.43	□				#	#	#							#	DZRC 1288 - 1290
P. occidentalis	87	4.13	●		#		#	#	#	#	#	#	#				1270 - 1286
Protopolybia exigua	1	0.05	X	#													MPEG 11.101.714 - 11.101.725
Synoeca cyanea	4	0.19	X	#										#			DZRC 1253
Mischocyttarus cassununga	9	0.43	□							#	#	#	#	#	#		DZRC 1322 - 1326
M. parallelogrammus	12	0.57	●	#				#		#	#	#	#			#	DZRC 1316 - 1321
M. rotundicolis	5	0.24	□						#					#	#	#	MPEG 11.101.714 - 11.101.725
M. socialis	39	1.85	●	#	#	#	#	#		#	#	#	#	#	#	#	DZRC 1302 - 1315
M. wagneri	1	0.05	X				#										MPEG 11.101.713
Polistes carnifex	2	0.10	X											#	#		DZRC 1291
P. versicolor	32	1.52	●					#		#	#	#	#	#	#	#	DZRC 1292 - 1301
Number of individuals	2104			186	78	106	400	99	404	152	83	100	129	137	162	68	
Richness (S)	21			13	6	5	12	10	10	12	11	11	10	13	10	8	

Although there is no significant difference in species richness between the two seasons (z = 1.0714, p = 0.2840), one can observe (Figure 2A) that in the super humid season (Sm = 11) the average richness was greater than in the less humid season (Sm = 9). In the super humid season the lowest number of species collected was 10, in October, February and April, and greatest richness was 13 species in March. In the less humid season, there was a decreased richness mainly in the months of June and July, with six and five species, respectively. Despite the observed decrease in these months, in May 2007 the richness was equal to the highest found in the super humid season, or 13 species. This number is likely due to the fact that the month of May represents the beginning of the drier period, and therefore, wasp colonies have just recently been exposed to less favorable conditions.

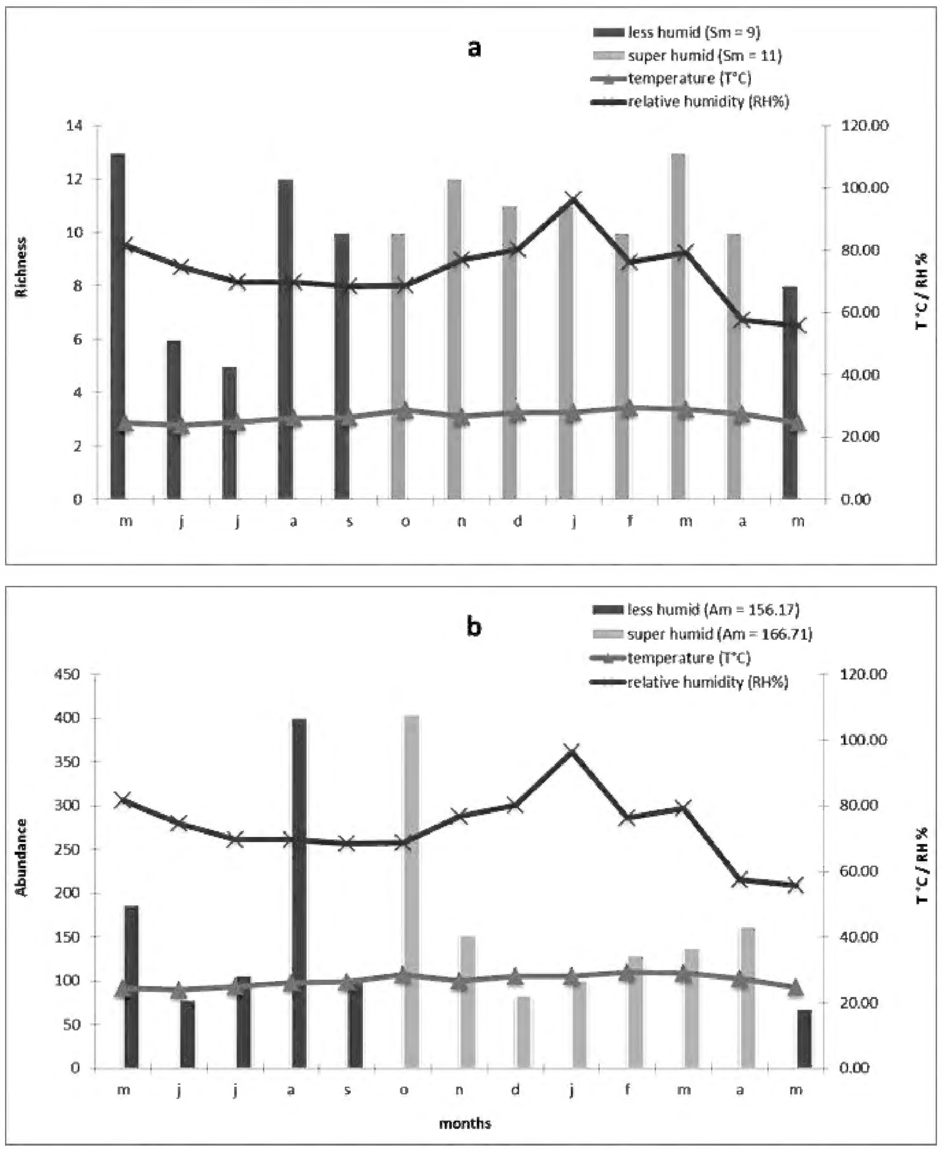

Figure 2. Diversity of social wasps related to temperature and relative humidity during the months of the year in Angelim Rainforest, Ubatuba, SP: (a) Richness of species (Sm = average richness of each season) and (b) Abundance of species (Am = mean abundance of each).

Table 3. Survey studies on social wasps in São Paulo state, Brazil.

LOCATIONS	N. OF SPECIES	N. OF GENERA	AUTHORS
Rio Claro	33	10	Rodrigues and Machado (1982)
Santa Rita do Passa Quatro	26	8	Mechi (2005)
Paulo de Faria	7	4	Gomes and Noll (2009)
Pindorama	6	4	
Neves Paulista	12	7	
Patrocínio Paulista	30	10	Lima *et al.* (2010)
Magda	20	8	Tanaka-Junior and Noll (2011)
Bebedouro	13	7	
Matão	13	6	
Barretos	19	8	

Regarding the number of individuals collected, a slight seasonal difference (not significant) was observed in mean abundance, with a value of 166.71 individuals at the super humid season and 156.17 in the less humid season. There was no significant difference in abundance between seasons (z = 0.8571, p = 0.3914), with observed peaks in August and October 2007 (Figure 2B).

Also in Figure 2, it can be noted that the environmental temperature varied little throughout the year, with the lowest temperature 23.87°C occurring in June 2007, and the highest (29.40°C) occurring in February 2008. Although lower values of richness, (especially in June and July) and lower rates of abundance (such as in May 2008), could be noted, probably as a result of the decrease in temperature, an increase in the diversity of social wasps was not observed in the warmer months. By using the Spearman test, it was not possible to establish a significant correlation between temperature and species richness (r = 0.2770, p = 0.3596) or abundance (r = 0.0604, p = 0.8445).

However, by examining the values of relative humidity greater than 80% recorded in May and December 2007 and January 2008, greater richness values can be noted (13, 11 and 11 respectively), while in June and July 2007 and May 2008, a smaller number of species were collected and are coincident with lower relative humidity (Figure 2A). This trend is confirmed by the Spearman test that showed a significant positive correlation between relative humidity and species richness of social wasps in Angelim Rainforest (r = 0.6435, p = 0.0176). Contrary to expectations, in May 2008 the lowest abundance and the lowest humidity were observed. There was no significant correlation between these variables (r = 0.0604, p = 0.8445), reflecting the lack of pattern in the relationship between species abundance and relative humidity in this study,

Discussion

Survey studies on this group of social wasps in Brazil have become relatively frequent (Table 3). Since 2005 at least two annual surveys related to the diversity of social wasps were published, however, knowledge on the richness of these communities in the Atlantic Forest remains scarce.

The studies of Melo *et al.* (2005), Hermes and Köhler (2006), Santos *et al.* (2007), Souza *et al.* (2008), Gomes and Noll (2009), Prezoto and Clemente (2010), Lima *et al.* (2010), and Tanaka Junior and Noll (2011) addressed regions of the Atlantic Forest, reporting quite different richness estimates from the present study. A lack of studies in São Paulo state is apparent, as evidenced in Table 3. Richards (1978) found 105 species (111 including subspecies) in museums around the world originating from municipalities in the state of São Paulo, with only the species *Apoica pallens* having not been previously listed by him. However, it should be noted that *Apoica pallens* had been listed by other authors for the state of São Paulo (Rodrigues and Machado 1982; Mechi 1996; Locher 2012).

Considering the results of inventories carried out in southeastern Brazil (Rodrigues and Machado 1982; Mechi 1996; 2005; Souza and Prezoto 2006; Elpino-Campos *et al.* 2007; Ribeiro Junior 2008; Souza *et al.* 2008; Clemente 2009; Gomes and Noll 2009; Alvarenga *et al.* 2010; Auad *et al.* 2010; Lima *et al.* 2010; Prezoto and Clemente 2010;

Souza *et al.* 2010; Henrique-Simões *et al.* 2011; Souza *et al.* 2011; Tanaka Junior and Noll 2011; Locher 2012), it is observed that the most abundant species in Ubatuba, *Agelaia angulata*, *A.* nr. *centralis* and *Angiopolybia pallens* were not collected in other studies, with the latter having been observed in another area of Atlantic Forest in Bahia (Santos *et al.* 2007). These three species are more common in the inventories of the North and Northeast regions of Brazil, generally covered by "cerrado" and Amazonian rainforests (Silveira 2002; Melo *et al.* 2005; Silveira *et al.* 2005; Santos *et al.* 2007; Morato *et al.* 2008; Silveira *et al.* 2008).

The species *Polybia catillifex* and *Mischocyttarus parallelogrammus,* which had high abundance in the Angelim Rainforest, were not listed in any other survey. Richards (1978) reported the occurrence of *M. parallelogrammus* only in the states of Minas Gerais, Rio de Janeiro and São Paulo. These data reinforce the need for more studies on the northern coast of São Paulo. This result may be related to the lack of studies in the Atlantic Forest, but can also be explained by the complexity of this biome. In a study on the community of social wasps of three ecosystems of Itaparica Island, in Bahia state (mangrove, ombrophilous dense forest and restinga), there was a significant correlation between plant diversity and the diversity of species of wasps (Santos *et al.* 2007). It was observed that the ombrophilous dense forest has a larger and more complex variety of plants than other biomes studied, and consequently a greater richness of the fauna, which can be explained by the heterogeneity of the environment and the existence of a wide variety of niches (Santos *et al.* 2007).

In general, species in the tribe Epiponini, especially those of the genus *Agelaia*, showed the greatest abundances. This result may be due to the population size of this group of swarm-founding wasps with medium to large colonies that may have millions of individuals (Zucchi *et al.* 1995). Moreover, in swarm-founding wasps, a greater specialization occurs among individuals in a colony, which reduces the chance of death of the queen and contributes to a more effective defense of the colony (Jeanne 1991).

The tribes Mischocyttarini and Polistini are independent-founding and have colonies composed of only a few dozen wasps (Richards 1978; Gadagkar 1991; Reeve 1991) which may be reflected in the low abundances found for these species. However, in this study, *M. parallelogrammus* and *P. versicolor* had low abundances, but were considered constant species. The remaining species *Agelaia vicina, Apoica pallens, Polybia jurinei, Mischocyttarus cassununga* and *M. rotundicolis*, were considered acccidental species. Thus, of the twenty-one species collected, nine (42.86%) were classified as constant species, five (23.81%) were considered accessory species and seven (33.33%) were accidental species. The high percentage of constant species may also be explained by the high complexity of the ombrophilous dense forest, which has numerous food resources that can provide greater chances of survival and reproduction (Santos *et al.* 2007).

The greatest number of species of wasps sampled in more humid conditions does not mean that a larger number of individuals perform foraging activity under these conditions, but may mean that this period has better environmental conditions, contributing to a higher richness of species to found their colonies. At the localities: "Mata do Baú" in the city of Barroso, Minas Gerais state, "Patrocínio Paulista", SP and "Ibitipoca State Park" in the city of Lima Duarte, MG, the highest species richness values were observed in the warmer and humid months of the year (Souza and Prezoto 2006; Lima 2008; Ribeiro Junior 2008; Clemente 2009). Thus, it can be seen in Figure 2B, that in August and October 2007, which were the months with highest abundances, high relative humidity was not observed. In the wettest month, January 2008, there was a relatively low number of individuals, corroborating the data that humidity and foraging would be inversely proportional. Moreover, the high relative humidity during this period may be due to high rainfall that reduces flight activity (Giannotti *et al.* 1995; Andrade and Prezoto 2001; Resende *et al.* 2001).

Overall, this study, despite not having observed a very high species richness compared with other surveys, is of great importance with regards to the need for further studies in the region and the collection of species with low occurrence records in southeastern Brazil such as *Mischocyttarus parallelogrammus* and *Polybia catillifex*. Furthermore, this study emphasizes the complexity of the Atlantic Forest biome and its relation to the diversity of wasps, with the frequent collection of species common in the Amazon Forest: *Agelaia angulata, A. sp. prox. centralis and Angiopolybia pallens*. A correlation between species richness and relative humidity was also noted, demonstrating the influence abiotic factors can have on populations.

Acknowledgments: We thank the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for financial support.

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Received: July 2013
Accepted: December 2013
Published online: February 2014
Editorial responsibility: Matthew Smart